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Phosphorus and nitrogen management in Austria as an example for coupled resource management systems

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The tremendous increase in resource consumption over the past century is one of the biggest environmental challenges the world faces today. A shift from a linear to a circular resource use is therefore increasingly getting into focus. However, to date most resource studies are restricted to one material or a single sector or process. This study simultaneously looks at phosphorus (P) and nitrogen (N) management and options for improvement in the national context of Austria, in order to identify co-benefits and negative side-effects between the two substances. Both P and N are essential fertilizers in agriculture. However, while for P resource scarcity becomes a more and more pressing issue, production of mineral N-fertilizer requires high amounts of energy and reactive forms of N released to the environment contribute to various environmental problems like air pollution, eutrophication and climate change.

The analysis is based on a coupled material flow analysis (MFA) for P and N. The freeware STAN is used to calculate mass balances and to perform error propagation and data reconciliation. Uncertainty of model input data is characterized by combination of qualitative data classification and exponential-type uncertainty characterization functions. The coupling of the P and N balance is achieved by introducing a goods-layer into the system, which represents the total mass of a stock or flow. Coupling takes place during data reconciliation, when masses and concentrations of flows are adjusted so that the mass balance for all processes is kept on both the P and the N layer. To evaluate the effects of different management options, scenarios looking at measures to reduce P and/or N-demand, increase recycling or reduce their losses to air or water are compared to a reference state, representing the actual situation in 2015. Indicators used for assessment include the demand of mineral P- and N-fertilizer, emissions to air (N only) and water bodies, P accumulation in agricultural soil as well as losses in the waste sector.

Overall measures to improve P-management have positive effects on the N-system and vice versa, which is why highest efficiency gains can be achieved by a combination of all the 16 measures studied. Large potentials lie in the reduction of mineral fertilizer demand, whereas emissions to water bodies can only be reduced to a lesser extent. This is partly an effect of successful emission reduction measures in the past and shows that society to date has made more progress in environmental- than in resource protection.

Although coupling significantly raises model complexity, the combined MFA reveals interrelations between P and N management and co-benefits of management strategies that might have been overlooked in a single substance analysis. This opens the door to including other substances that might be affected by P and N management into the system, to extend the MFA with elements of entropy analysis or life-cycle assessment for better coverage of environmental effects of different measures and to developing frameworks for the analysis of coupled resource systems in general.